RUSSIAN DEMANTOID, CZAR OF THE GARNET FAMILY

By Wm. Revell Phillips and Anatoly S.Talantsev

Demantoid, green andradite garnet, was discovered in the Central Ural Mountains of Russia in the mid-19th century. A favorite of the Czar's court, demantoid was another victim of the 1917 Bolshevik Revolution, when mining of this and other Russian gems was halted. Today, however, independent miners are recovering notable quantities of stream-worn demantoid pebbles from two major districts: Nizhniy Tagil, about 115 km north, and Sissertsk, about 75 km south, of Ekaterinburg. As a result, these distinctive bright "golden" green to dark green garnets are re-emerging in the gem market. Although cut stones continue to be small for the most part, a number of fine demantoids over 1 ct have been seen.

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The popular garnet family is one of the most prolific mineral groups, with a family tree rooted primarily in five common end-member garnets and branching to a spectrum of colors and gem varieties. Historically, garnet was loved for its deep, rich red color, and the word *pyrope* is derived from the Greek word meaning "fire-like" (Dana, 1958).

The green garnets are of a younger generation and the "darlings" of the family. Demantoid emerged first, in the 19th century, when it entered the royal courts of Czarist Russia from the valleys of the Ural Mountains. Purged in the early 20th century by the Bolshevik revolution, demantoid all but disappeared from the international gem scene. In recent decades, it was largely replaced by its younger sibling, tsavorite, from the East African bush country. In a new Russia, however, the demantoid sites are again becoming active, with a trickle of green fire reentering the market (figure 1).

Demantoid ($Ca_3Fe_2[SiO_4]_3$) is the chromium-green gem variety of andradite, but it usually exhibits a yellow overtone due to intrinsic ferric iron. With a hardness slightly less than 7, demantoid is not a good ring stone. However, its high index of refraction (1.89) and dispersion (0.057; diamond is 0.044) make it a gem of great brilliance and fire for other jewelry purposes.

The following account looks at the early history of demantoid as a gem material and its present status with regard to localities, geology, production, and marketing, as demantoid reemerges from virtual obscurity into a promising future. Locality information is based largely on the authors' own experience and knowledge of the Urals region. A review of demantoid's place in the garnet family helps explain its distinctive properties, especially in contrast to tsavorite, with which it has been compared in the trade.

HISTORY

About 1853, children from the settlement of Elizavetinskoye (also spelled "Elezavetinskaya"), southwest of the larger village of Nizhniy Tagil (also known as Nazhniy-

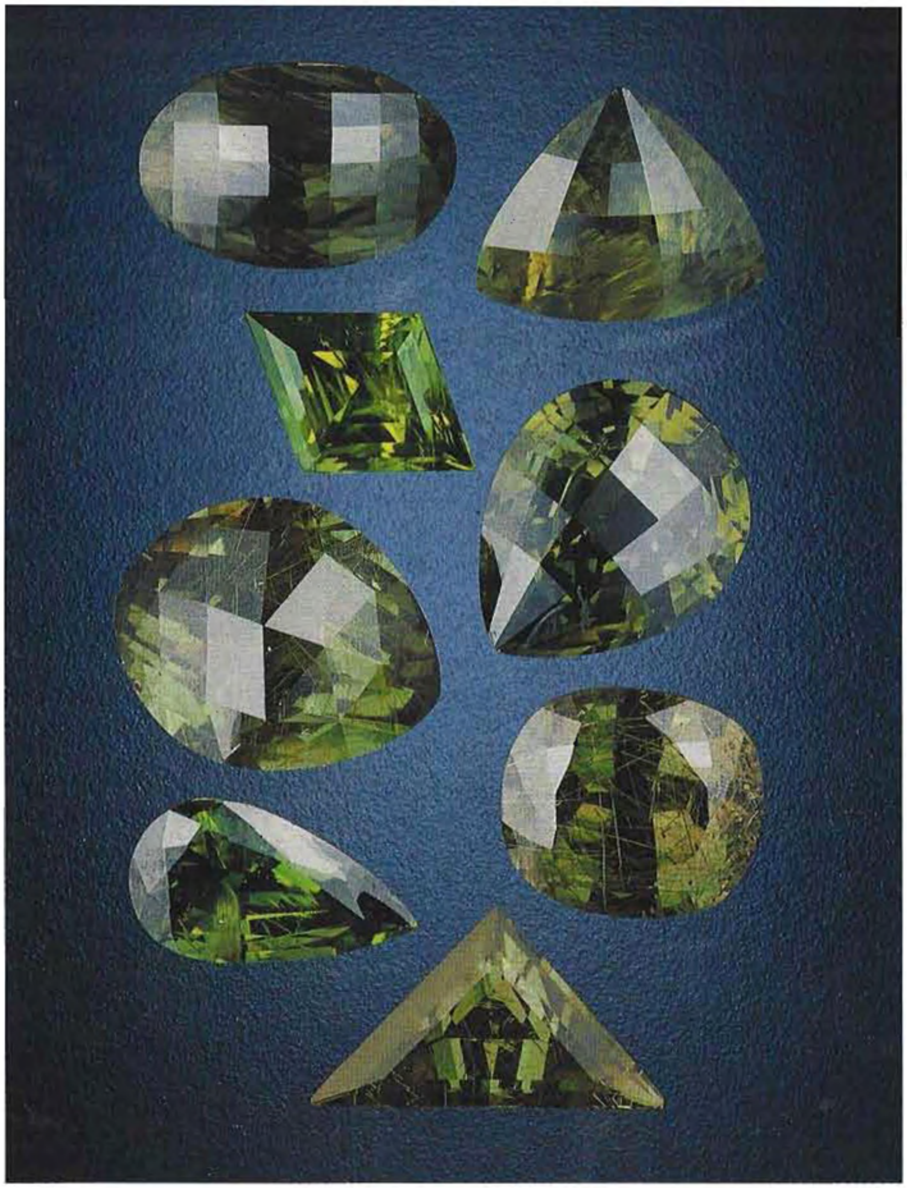


Figure 1. A number of fine demantoids from Russia have appeared in the gem market recently. These unusually large demantoids (1.64–5.40 ct) range from "golden" green to a deep "emerald" green. Stones courtesy of Gebr. Henn, Idar-Oberstein, Germany; photo © GIA and Tino Hammid.

Tagilsk) in the Central Urals (figure 2), found unusual "grass"-green pebbles (probably similar to those shown in figure 3) in the heavy spring runoff of the Bobrovka River (Eichmann, 1870; Samsonov and Turingue, 1985). Local jewelers identified the green gem as chrysolite (olivine, [(Mg, Fe)$_2$SiO$_4$]—generally known by gemologists as *peridot*). Mineral collecting was very stylish in late-19th-century Czarist Russia, especially among the nobility, and mineral collectors soon converged on Nizhniy Tagil in search of specimens of this gem. This "Ural chrysolite" (which also was called "Bobrovsk emerald," "Uralian emerald," and "Siberian chrysolite") soon appeared in the jewelry shops of Moscow and St. Petersburg, mostly as small, fiery calibrated stones framing enamel work or the larger gems of the Urals, such as pink topaz or beryl.

Nils von Nordensheld (also spelled "Nordenskiöld"), a Finnish mineralogist who first gained fame in the Urals with his identification of the new mineral phenakite (Be$_2$SiO$_4$), arrived at Nizhniy Tagil a year after the initial demantoid discovery. He remained for a year and a half studying copper deposits in the area. P.V. Eremeyer (also spelled "Eremeev"), his friend and biographer, suggests that von Nordensheld never visited the actual site where the green stones were found, but rather examined those in several collections. On the basis of these examinations, von Nordensheld declared the green gem a new mineral and certainly not chrysolite.

On February 20, 1864, von Nordensheld described the beautiful green gem before the St. Petersburg Mineralogical Society as green andradite garnet colored by a small chromium content (Eremeyer, 1871). The fact that andradite has the highest R.I. and dispersion of any of the garnets explained the unusual brilliance and fire, and he proposed the name *demantoid* (i.e., "diamond-like") for the little "green diamonds" (Clark, 1993,

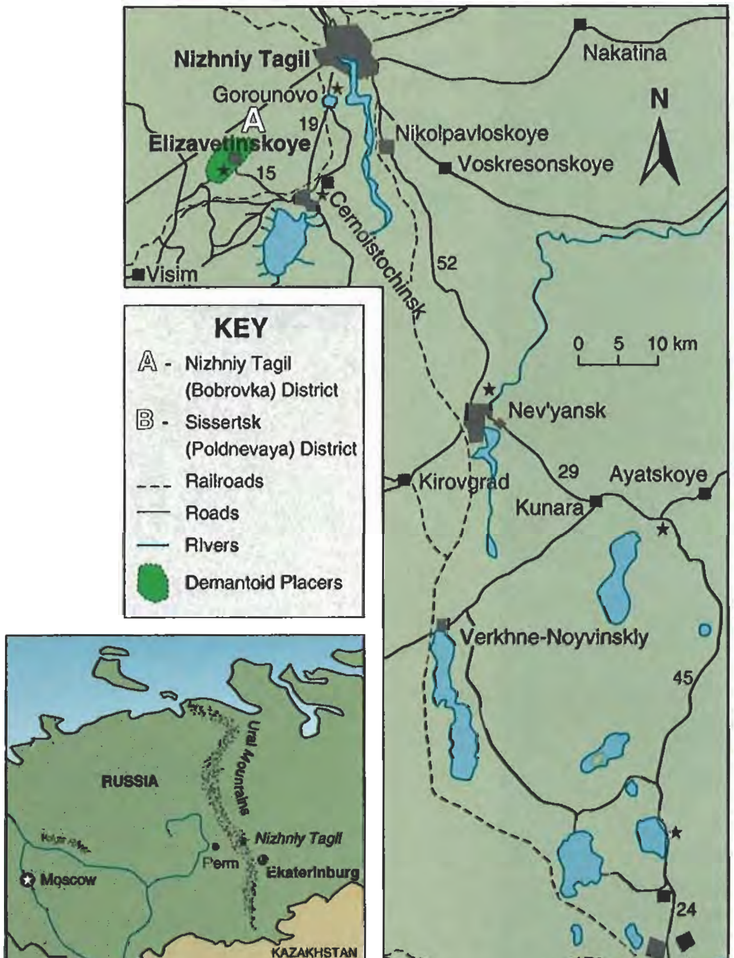


Figure 2. The main two demantoid localities described in this article are reached by paved and unsurfaced roads from Ekaterinburg, the largest city of the Central Urals in Russia. The northern—Nizhniy Tagil (A)—district is near Elizavetinskoye, about 35 km by road south-southwest of Nizlniy Tagil. The southern—Sissertsk (B)—district lies between Poldnevaya and Verkhniy Ufaley, about 35 km by road south of Polevsk'oy. The numbers on the roads represent the number of kilometers between the distance markers (stars).

p. 176, gives 1878 as the year the term was introduced and first published). The name was accepted subsequently by Russian mineralogists and jewelers, but it was initially rejected by the local people, who continued to call it "Ural chrysolite," as *demantoid* sounded too much like a word that was vulgar in the local dialect.

A second discovery was made about 75 km (90 km by road) south of Ekaterinburg in the Sissertsk (also spelled "Sysert" and "Syssert") District (also referred to as the Polevsk'oy District or Poldnevaya District) on the Chusovaya and Chrisolitka Rivers of the west slopes of the Ural Mountains. This area produced gems equal, or superior, in quality to those at the first locality (Church, 1879).

Demantoid was very popular in Russia from about 1875 to 1920 (figure 4). It was even incorporated into some of the fabulous creations of Peter Carl Fabergé and other court jewelers. Although most of these gems were used by the Russians, who preferred the brownish or yellow-green stones (R. Schafer, pers. comm., 1996), a few—including the less popular (and less brilliant) intense green gems—were exported to the European market at exorbitant prices. Edward VII of England favored green gems, and demantoid entered the "Belle Epoque" (see cover and figure 5).

Serious efforts have been made to find demantoid deposits in similar geologic environments elsewhere in Russia. In 1980, one was reported at a site in the Kamchatka Peninsula of eastern Siberia. The stones are usually small (2–3 mm) but of good quality. Several deposits of yellow andradite (sometimes referred to as "topazolite," although this term is in

Figure 3. These pebbles, in the form of abraded dodecahedra, are typical of the alluvial demantoids found in the Central Urals. The stone on the left clearly shows the spray of radiating "horsetail" fibers that is characteristic of demantoid garnets. From left to right, they weigh 6.63, 4.81, and 4.62 ct. Photo by David W. Hawkinson, BYU Museum of Art.

disfavor with modern gemologists) and uvarovite (the chrome analog of andradite) also came to light. Minor occurrences of demantoid also have been reported from Zaire, Korea, Sri Lanka (gem gravels), California (San Benito County; Payne, 1981), and south-central Mexico (Wilson, 1985). Even some stones from the Ala Valley of Italy are green enough to be considered demantoid. Nevertheless, demantoid has largely remained a gem of the Ural Mountains (Samsonov and Turinge, 1985). Crystals from all of these other localities are rare, seldom more than a few millimeters, usually very pale, with cut stones over one-quarter carat rare indeed.

With the onset of the Bolshevik Revolution in 1917, gems went out of vogue in Russia, along with other symbols of wealth and royalty, and Soviet resources turned to mineral production more in demand by industry. Localities of emerald and other beryls were mined for their beryllium, diamond was mined for industrial applications, and the tailings piles of chrysoberyl mines were hand-picked for molybdenite. In the early stages of World War II, Joseph Stalin moved the Soviet heavy industry to the Central Urals, away from immediate Nazi invasion. The Urals produced planes, tanks, and guns for a desperate nation; demantoid and other gems for personal adornment seemed unimportant.

Figure 4. Popular in Russian jewelry from 1875 to 1920, demantoids provide a field of green for this antique star brooch manufactured in Russia. Courtesy of À La Vielle Russie, New York City; photo by Nicholas DelRe.

Figure 5. Demantoids were particularly popular in late 19th- and early 20th-century Edwardian jewelry. This yellow-gold and silver 19th-century dragonfly pin is set with two relatively large demantoids—1.30 and 1.03 ct—in the main body, as well as assorted smaller demantoids (2.80 ct total weight) throughout the balance of the piece, together with diamonds and two rubies. Courtesy of the Susan Clark Gallery of Gem Art, Vancouver, BC, Canada.

LOCATION AND ACCESS

Two major districts in the Central Ural Mountains of Russia have historically yielded demantoid garnet: Nizhniy Tagil (along the Bobrovka River) and Sissertsk (near Polevsk'oy and Poldnevaya). These regions are alternating dense forest (spruce, pine, aspen and birch) and open meadows, with much of the area marshland (figure 6).

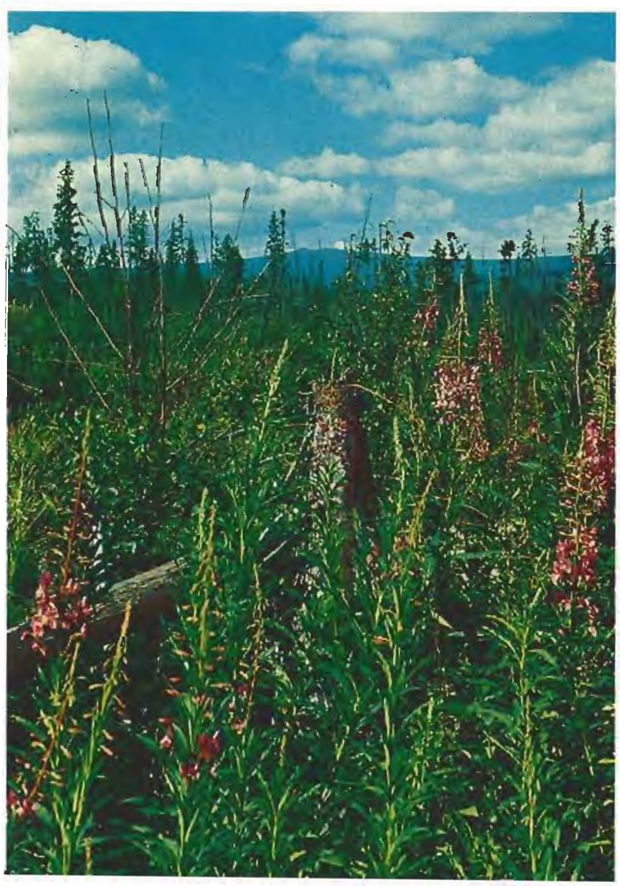
The Nizhniy Tagil district is near the tiny village of Elizavetinskoye, about 115 km north-northwest of Ekaterinburg (figure 7). It is best accessed from there via Nev'yansk and Nizhniy Tagil over paved roads. This district contains two deposits: (1) the placer on the Bobrovka River (Bobrovskaya Placer), which runs for about 2 km through Elizavetinskoye; and (2) a primary, *in situ*, deposit at the head of the Bobrovka River (Tochilny Kluch), which is the source of the alluvial demantoid.

The Sissertsk district lies between Poldnevaya and Verkhniy-Ufaley near the Korkodin railway station, which is about 75 km south-southwest of Ekaterinburg (figure 8). All but 4 km of the road from Ekaterinburg to the site (90 km), via Polevsk'oy, is paved. In this district there are two primary, *in situ*, deposits: at Kladovka (point I in figure 8) and at Korkodin (point II in figure 8). In addition, there are five river placers: Bobrovka (area 1, figure 8), Zyachiy Log ("Hare Creek," area 2), Ufaleyka (area 3), Chrisolitka (area 4), and Kamenuschka (area 5). (Note that the Bobrovka area in the Sissertsk district should not be confused with the larger Bobrovka River that is in the Nizhniy Tagil district.)

In 1985, a small demantoid deposit was discovered in the southern part of the Arctic Urals on the Hulga River. This new deposit contains both *in situ* demantoid and a small placer. Crystals are gem quality, relatively large (6–8 mm), and good green color. The site is difficult to reach and has not been studied.

In 1995, another demantoid deposit was reported in the Arctic Urals on the Hadata River. The primary deposit is on the Saum-Kev pyroxenite massif and is accompanied by a placer deposit about 1 km long. It is scheduled for exploration and study in the summer of 1996.

Figure 6. There is no formal mining site at Nizhniy Tagil. Rather, alluvial pebbles of demantoid are recovered from stream beds in a complex of low, mature hills covered by dense forest—largely birch, pine, aspen, and spruce—and, as shown here, open meadows.



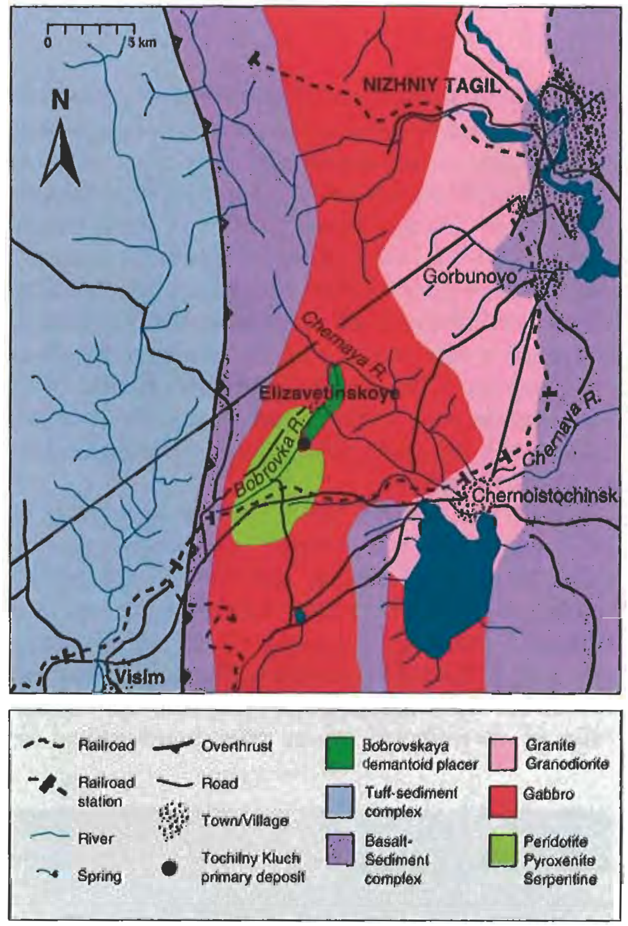


Figure 7. Demantoid was first discovered in gravels of the Bobrovka River near the small settlement of Elizavetinskoye, in what is now called the Nizhniy Tagil district. Primary crystals are also recovered from the peridotite intrusion south of the village, at Tochilny Kluch, where the demantoid forms in thin chrysotile veins in serpentinized pyroxenites.

GEOLOGY AND OCCURRENCE

In the Central Urals, primary deposits of demantoid crystals occur in both major districts, as shown in figures 7 and 8. At Nizhniy Tagil, serpentine lenses about 1.5 km long by 200–300 m wide occur within ultramafic (pyroxenite-peridotite) intrusions, and are cut by veins of coarse-grained olivine (chrysolite) and minor dolomite. At Tochilny Kluch (="Creek"), the demantoid crystals appear to form around tiny grains of chromite in the highly fractured contact zones between chrysolite veins and serpentine. Ultramafic rocks—such as peridotite, pyroxenite, and their alteration product, serpentine—usually contain high concentrations of chromium and are the source both of chromite ($FeCr_2O_4$) and of the chromium for a plethora of

Cr-bearing minerals, including emerald, alexandrite, and demantoid.

Because demantoid crystals are relatively soft and brittle, they will not withstand the rigors of extensive stream transportation. Alluvial pebbles of demantoid (again, see figure 3) are found largely in the sandy gravels of the shallow headwaters of small streams fed by large springs (Samsonov and Turinge, 1985). Demantoid in the Nizhniy Tagil district is recovered from Pleistocene river gravels cut by the active Bobrovka River; the principal deposit measures about 500 m along the river valley and is 20 to 100 m wide (again, see figure 7). The productive sandy, red gravels (sand-size to gravel-size grains and pebbles of the available rock types, stained red by iron oxides from the weathering of the iron-rich rocks) are as much as 2.5 m thick. They lie on an eroded surface of Paleozoic volcano-sediments, and are covered by several meters of detritus and soil. The best horizons are near the base of ancient terraces; these may contain 100 g of demantoid per cubic meter, 80% of which are pebbles of 4 mm or less. A second deposit on the Bobrovka (also within the placer area marked in figure 7) is even larger (2.5 km by 50–60 m); much of the Pleistocene sand and gravel lies below the present stream cut and may reach a total thickness of 6 m. Only the modern river bed has been exploited for demantoid crystals, which are poorly formed dodecahedra {110} and may reach 5–6 cm, although such large crystals are very rare.

The geology and deposits of the Sissertsk (Poldnevaya) district are similar to those of Nizhniy Tagil (again, see figure 8). At both primary deposits, demantoid occurs in thin (1.5–2 cm) chrysotile veins in serpentinized pyroxenites. Thus far, these primary sites have produced only mineral specimens. In all of the five placer deposits, demantoid is recovered from the lowest gravel bed (the basal bed), with minor amounts from sand bars.

MINING AND PRODUCTION

Mining specifically for demantoid in Russia has been very erratic. Before 1915, the stones were usually obtained as a by-product of platinum mining of the placers at Elizavetinskoye and gold mining of the placers in the Sissertsk district. Since then, the demantoid deposits have been worked mostly by private miners (figure 9), operating illegally, who search river gravels or dig pits up to 5 m deep and then wash and screen the pit gravels. Only the contract companies have licenses to dig, and even

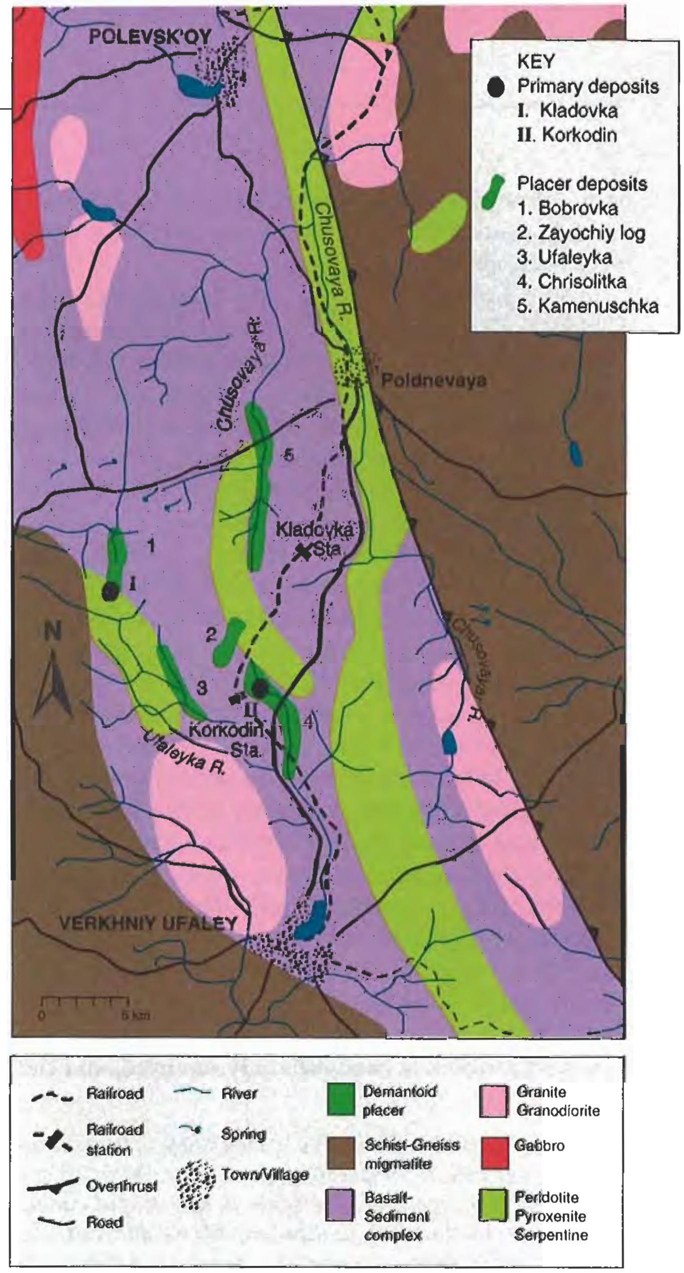


Figure 8. In the Sissertsk demantoid district, the garnets occur as primary crystals in serpentinite pods in ultramafic pyroxenites and as detrital pebbles in stream gravels a few kilometers west of the Kladovka railway station or north of the Korkodin station.

those may be for exploration only. Illegal digging is a dangerous profession, as the authorities are always alert and local competition is keen. Miners have been subject to arrests, threats, and even shootings.

In the 1970s, government geologists studied the Nizhniy Tagil–Elizavetinskoye deposits for commercial development, and for three to five years thereafter, the AO Uralquartzsamotsvety ("Ural-quartz-colored stones" Company) attempted hydraulic mining. Recovery was poor (40%–60%), and much high-quality rough was lost in the tailings. However, most of the demantoid was ultimately recovered by the local people, who work over every dump and tailings pile.

A very crude estimate would suggest that, prior to 1990, a total of perhaps 200 kg of demantoid rough had been mined; the total remaining commercial reserve of the Elizavetinskoye placers has been estimated at 2,000–3,000 kg. In 1993, the deposit was licensed to a metallurgical company (AO NTMK [Nizhniy Tagil Metallurgical Kombinat]) for prospecting, but no commercial production has resulted. The license expires in 1997, and the company is desperately seeking foreign financing.

The Korkodin-Chrisolitka deposit was explored in the late 1980s, and a license was purchased by a private conglomerate (TOO "Grani") from the Chelyabinsk region. A production company was formed, and some small-scale organized mining began in 1994; however, no commercial production has yet been reported. Reserves at the Korkodin-Chrisolitka deposit are estimated at 5,000 kg.

The Kamenuschka deposit, about 5 km north of Korkodin, is unexploited, unlicensed, and remains available for development. Trenches cut by "bandit diggers" expose the bedrock and reveal demantoid in drusy cavities, which are valued both for jewelry and as mineral specimens. No commercial production has been officially reported, and the reserves at the Kamenuschka deposit are estimated at roughly 2,000–3,000 kg.

Figure 9. In the Urals, most of the demantoids are recovered by local villagers who illegally search the river gravels. Here, a Russian woman examines gravels from the Bobrovka River.

Figure 10. These five stones (0.24–0.35 ct) were selected from a collection of about 50 small cut stones to represent the range of demantoid colors. On the basis of qualitative EDXRF analysis, the bright green stone on the far left contains much more chromium than any of the others, and the near-colorless stone on the far right contains much less. The three center stones all have about the same chromium content, between that of the previous two samples. By comparison, a medium-green tsavorite garnet analyzed revealed more chromium than all but the brightest green demantoid here, but it also had 10 to 100 times more vanadium than chromium. Photo by David W. Hawkinson, BYU Museum of Art.

Unofficial estimates place total demantoid rough production for 1995 at about 8 kg (Elizavetinskoye—5 kg, Poldnevaya—3 kg). About 40% of this total, some 16,000 carats, is recovered as cut stones. Less than 10% of the latter group, about 1,600 carats, is represented by stones of one carat or more.

Little more can be said at this time about the present status or future development of demantoid garnet in the Ural Mountains of Russia, except that interest is growing, foreign investors are welcome, and proposals to develop the deposits are under consideration. However, all of the areas containing demantoid, except Korkodin, supply drinking water to local cities, so the serious development of any one of them could become an environmental concern.

MATERIALS AND METHODS

The senior author selected from his collection of about 50 Russian demantoids five small cut stones (0.24 to 0.35 ct.) that ranged from the deepest green to almost colorless (figure 10). In addition, for comparative spectral analysis he included one yellowish brown andradite from Coyote Front Range, Inyo, California; one medium green tsavorite from east Africa; and one colorless grossular from Wakefield, Canada.

Qualitative energy-dispersive X-ray fluorescence (EDXRF) analysis was performed on these samples at Brigham Young University, solely to determine the presence or absence of chromium in the five samples. The UV-visible spectra were obtained by the senior author with a Hewlett-Packard HP8452A diode array spectrophotometer, also at BYU, on one medium-green demantoid as well as on each of the tsavorite, andradite, and grossular samples described above. Details of analyses are available on request from the senior author.

DESCRIPTION OF THE DEMANTOIDS

Demantoid garnet is gem-quality green andradite ($Ca_3Fe_2[SiO_4]_3$), usually very near the ideal andradite composition, 97.02 wt.% to 99.67 wt.% andradite (Stockton and Manson, 1985), with minor chromium contributing the valued green color, and traces of aluminum, titanium, vanadium, and sometimes manganese. Demantoid ranges from yellowish or brownish green to "golden" green (figure 11), and—the rarest—"emerald" green (again, see figure 1). The gemological properties are consistent with those for other garnets (see table A-1 in Box A), with the exception of the unusually high R.I. (1.89) and dispersion (0.57). As noted earlier, for the most part demantoids are small, less than 1 ct. Although the authors have heard of at least one faceted stone over 21 ct (S. Fesenko, pers. comm., 1996), this is extraordinarily rare.

Figure 11. One of the most distinctive demantoid colors is this bright yellowish or "golden" green color. These two Russian demantoids, 1.36 ct (round brilliant) and 1.08 ct, are courtesy of Mayer & Watt, Maysville, Kentucky. Photo © GIA and Tino Hammid.

Cause of Color. Cr^{3+} substitution for Fe^{3+} in octahedral Y sites (again, see Box A) is responsible for the rich "grass" green of demantoid, which is superimposed over the yellow overtone contributed by the intrinsic ferric iron of andradite (figure 12). Cr-bearing demantoid shows red through the

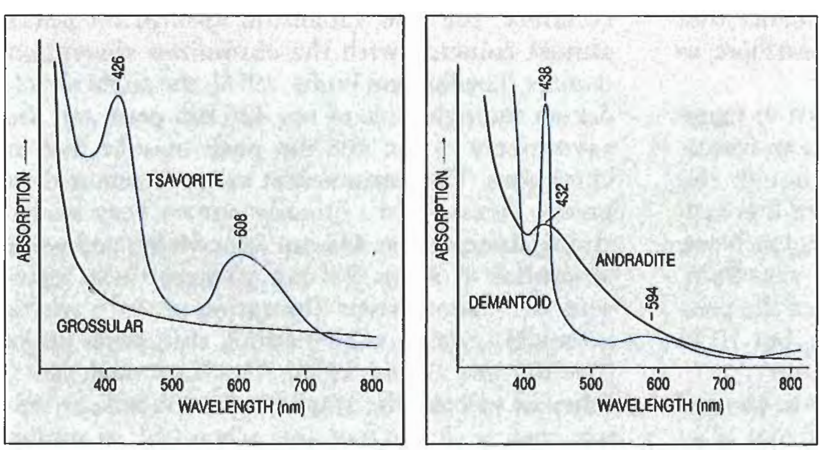


Figure 12. These UV-Visible spectra for a medium green tsavorite garnet from East Africa and a medium yellowish green demantoid garnet from the Central Urals clearly separate the two green garnets and also illustrate the greater influence of chromium in the demantoid. The spectra shown for samples of andradite and grossular that lack significant chromium and vanadium, illustrate the effects of these chromogens on these garnet types. The andradite is a brownish yellow sample from Coyote Front Range, Inyo, California, and the colorless grossular is from Wakefield, Canada.

BOX A: Demantoid's Place in the Garnet Group

The general formula for the garnet group is $X_3Y_2(SiO_4)_3$: where X = divalent ions with eightfold coordination, primarily Ca^{2+}, Mg^{2+}, Fe^{2+}, and Mn^{2+}; and Y = trivalent ions with sixfold coordination, primarily Al^{3+}, Fe^{3+}, V^{3+}, and Cr^{3+}. Nature combines X and Y elements to form real garnets depending on the availability of elements and the pressure and temperature of formation; it seldom, if ever, forms a pure, end-member garnet (i.e., one in which only one ion occupies the X site and one the Y site). Within the garnet group, the six most important end members, grouped by series, are: (1) uvarovite $[Ca_3Cr_2(SiO_4)_3]$, grossular $[Ca_3Al_2(SiO_4)_3]$, and andradite $[Ca_3Fe^{3+}{}_2(SiO_4)_3]$ (the calcium series); and (2) pyrope $[Mg_3Al_2(SiO_4)_3]$, almandine $[Fe^{2+}{}_3Al_2(SiO_4)_3]$, and spessartine $[Mn_3Al_2(SiO_4)_3]$. Recently, a seventh garnet species in the Ca series, *goldmanite* $[Ca_3V_2(SiO_4)_3]$, has gained significance for gemologists, as it forms solid solution with grossular to produce tsavorite.

Demantoid is an andradite garnet. Complete solid solution is possible between grossular and andradite, and individual members of this series (notably, demantoid) may contain minor Cr_2O_3 in partial solid solution with uvarovite, their chromium analog.

The green gem varieties tsavorite and demantoid both lie near the ideal end-member compositions, respectively, of grossular and andradite (Stockton and Manson, 1985). However, intermediate (yellow, not Cr-containing) grossular-andradite gems recently have been noted (Hurwit et al., 1994; Johnson et al., 1995). Selected optical and physical properties of garnets in the Ca series are presented in table A-1. The individual species, and their relationship to demantoid, are discussed below.

Andradite forms a complete solid solution with grossular, and intermediate compositions are common (Stockton and Manson, 1983; Griffen, 1992); however, gem-quality specimens of both andradite and grossular occur, in nature, usually with compositions near their ideal end-members. Andradite is intrinsically colored as a consequence of ferric iron (Fe^{3+}) in sixfold coordination (Y site), which produces yellow (Loeffler and Burns, 1976). Yellow or yellow-green andradite gems (once referred to as "topazolite," a term now in disfavor) are attractive but rare (Gill, 1978; Webster, 1983). Demantoid results when Cr^{3+} from solid solution with uvarovite substitutes for Fe^{3+} in the Y sites and superimposes a green color over the intrinsic yellow.

Schorlomite $[Ca_3(Fe,Ti)_2(Si,Fe)_3O_{12}]$ is a black garnet colored by Ti^{4+} and Mn^{2+} in combination with intrinsic ferric iron (Phillips and Griffen, 1981) that occurs in solid solution with andradite to yield "melanite," a Ti-rich black andradite. These black garnets have little gem application except in mourning jewelry, which was popular with the late Victorians, as an alternative to jet or black onyx.

Uvarovite is a beautiful green garnet in small sizes, with larger specimens so dark as to appear almost

Chelsea filter in proportion to the amount of chromium present. It typically shows no color zoning; however, the color is patchy (i.e., not homogeneous), and the senior author has observed intense green surrounding tiny chromite grains that appear to act as nucleation points for the demantoid crystals (figure 13). This is also graphic evidence that dissolution of chromite frees Cr to contribute to the green color of the demantoid.

EDXRF analysis of the stones shown in figure 10 confirmed that the intense color was an indication of high chromium content, although the stones of the medium color range showed less variability in chromium than in apparent color. None of these five stones showed measurable vanadium. The single East African tsavorite revealed the presence of both chromium and vanadium, but 10 to 100 times more of the latter than the former.

Both the demantoid and the tsavorite showed two major absorption peaks (again, see figure 12)—one in the blue and violet wavelengths, with lesser absorption in the orange and yellow range—and transmit green and red wavelengths. Also evident in figure 12, the tsavorite showed strong absorption peaks at 426 and 608 nm, which are attributed largely to V^{3+} modified by lesser Cr^{3+}. Unfortunately, the two vanadium absorption peaks almost coincide with the chromium absorption doublet (Loeffler and Burns, 1976); the slight shoulder on the right side of the 426 nm peak and the asymmetry of the 608 nm peak may be due to chromium. The transmission valley is centered on green. Demantoid typically shows very sharp, strong absorption at 438 nm (blue-violet) and weak absorption at about 594 nm (orange); these represent the characteristic absorption of Cr^{3+}, which normally consists of two strong absorption peaks (Loeffler and Burns, 1976). The ferric iron (Fe^{3+}) inherent to andradite amplifies the 438 nm chromium peak in demantoid and, when Cr^{3+} is minor,

Table A-1. Selected properties of garnets in the ugrandite (uvarovite-grossular-andradite) series.

Garnet species/ gem variety	R.I.	S.G.	Hardness	Dispersion
Andradite [a,b,c]	1.880–1.886	3.77–3.88	6½	0.057
Demantoid [a]	1.880–1.889	3.80–3.88	6½	0.057
Uvarovite [a,b]	1.798–1.868	3.71–3.81	7½	
Grossular [a,b]	1.731–1.760	3.40–3.78	7	0.028
Tsavorite [a]	1.739–1.744	3.57–3.65	7	0.028
Goldmanite [d]	1.821	3.75		
Intermediate (Mali) [e]	1.752–1.782	3.63–3.70		

[a] From Rouse (1986).
[b] Calculated value from McConnell (1964).
[c] From Stockton and Manson (1985).
[d] From Moench and Meyrowitz (1964).
[e] From Johnson et al. (1995).

black. It occurs mostly as drusy layers of tiny dodecahedral crystals in fractures in chromite. It is sometimes used for jewelry, showing tiny, bright green scintillation points. Uvarovite is typically associated directly with chromite spinel ($FeCr_2O_4$).

Grossular is colorless when pure; the addition of transition-element impurities (Fe^{3+}, Mn^{3+}, Cr^{3+}, V^{3+}) produces a wide variety of colors. For example, the hessonite variety (colored by Fe^{3+}) ranges from brownish yellow to orange-red, and manganese varieties are pink.

Tsavorite (also "tsavolite") is gem-quality transparent green grossular in partial solid solution with goldmanite, which contributes vanadium as the primary source of color. It is a recent addition to the garnet family, having been discovered in the 1960s in Kenya and introduced to the gem community in 1974 (Bridges, 1974). As much as 3 wt.% V_2O_3 has been recorded in some stones (Muije et al., 1971). Some specimens are colored solely by vanadium, but others contain a subordinate contribution from chromium and may even appear red through the Chelsea filter. Tsavorite ranges from intense "emerald" green (the most valuable) through yellow-green to almost colorless. Good-color gem tsavorites over 3 ct are very rare (Rouse, 1986, p. 100).

Goldmanite is a dark green to brownish green garnet that is much rarer (and much less attractive) than any of the other Ca garnets. It was first described in 1964 (Moench and Meyrowitz) from specimens found in Laguna, New Mexico, where it derives from the contact metamorphism of a uranium-vanadium ore deposit in a sandstone-limestone host rock.

demantoid transmits essentially all colors except violet. This yields strong yellow (red and green add to form yellow) with lesser blue, so the stone is green with a strong yellow overtone. As the Cr^{3+} content increases, the absorption peak at 594 nm becomes both higher and broader, absorbing orange and most of the yellow and red wavelengths. A similarly enlarged peak at 438 nm may absorb more short wavelengths, so that only green wavelengths are transmitted. Thus, Cr-rich demantoid may be "emerald" green without any modifying hue. A third high-energy Cr^{3+} absorption in the ultraviolet may be responsible for the red fluorescence of most Cr-colored gems.

Internal Features. The most distinctive internal feature of demantoid is its characteristic "horsetail" inclusion (again, see figure 13) which was present, whole or in part, in most of the Russian demantoids examined by the authors and which is found in no other green gem. In the gemological literature, the "horsetail" generally is referred to as hair-like byssolite (an obsolete name for asbestiform amphibole, usually of actinolite-tremolite composition) fibers that diverge from a focal point, usually a tiny opaque crystal of a spinel-group mineral, probably chromite or magnesiochromite. Recently, however, the horsetail fibers emanating from the chromite grains have been identified as serpentine (chrysotile) by Dr. A Peretti (pers. comm., 1996). Sometimes the fibers form a dense, eye-visible bundle (figure 14) or cone stained orange or brown by ferric oxide. Each demantoid crystal appears to nucleate on the tiny chromite crystal that also serves as a nucleation point for the serpentine "horsetail," so the demantoid and serpentine fibers must grow simultaneously. As the crystals are small, seldom large enough to cut more than one gem, each cut gem is likely to contain one horsetail, or the part thereof not removed by cut-

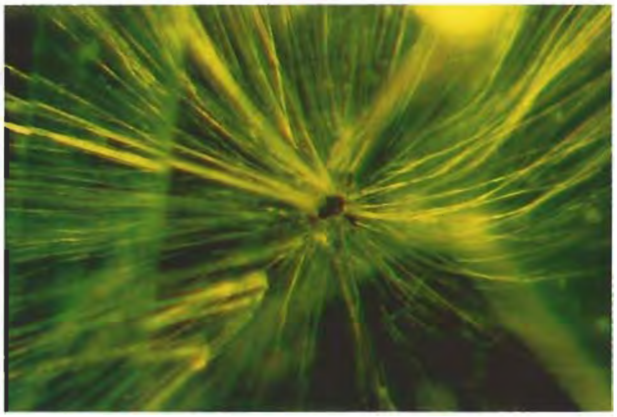


Figure 13. The most distinctive internal feature of demantoids is the "horsetail" of fibrous serpentine (chrysotile) that is present, in whole or in part, in most pebbles or cut gems. Note the tiny crystal (probably chromite) from which all the fibers radiate. Photomicrograph by John I. Koivula; magnified 20×.

Figure 14. In some demantoids, like this recently mined stone, the "horsetail" takes the form of a cone-like bundle of fibers. Photomicrograph by Shane F. McClure; magnified 20×.

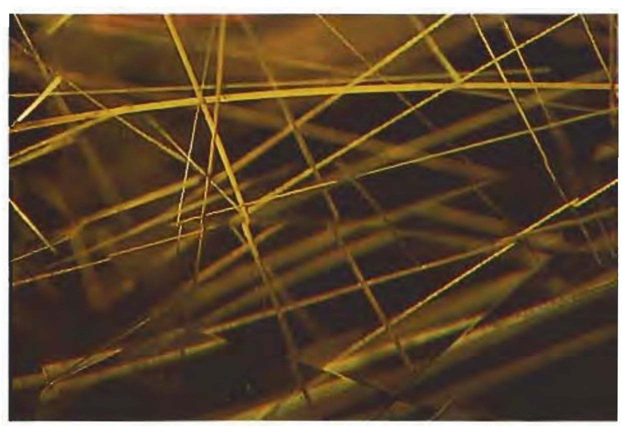
ting. In the authors' experience, cut specimens lacking all traces of a horsetail are exceedingly scarce. Rarely, the fibers are uniform and parallel, and the gem may be cut to show chatoyancy ("Cat's-eye demantoid," 1960). Some of the demantoids that have emerged most recently on the international gem market contain randomly oriented acicular inclusions that do not appear to be related to a "horsetail" (figure 15).

MARKETING AND DISTRIBUTION

Because of its extreme rarity, the small size of the crystals, and its relatively low hardness, demantoid has not enjoyed widespread recognition outside Russia. It was popular in the Western world for a brief period during the Edwardian age at the turn of the century, but it slipped back into relative obscurity after World War I, when little emerged from the young Soviet Union. Many of the demantoids seen in the market today are set in estate jewelry from the Edwardian period. Typically, demantoids appeared in Edwardian jewelry as a field of green melee or as an encircling band of melee or calibrated stones highlighting a much larger central stone. They also appeared in whimsical jewelry of the era, as bright green frogs, lizards, snakes, dragonflies (again, see figure 5), and the like (Misiorowski and Hays, 1993, p. 164).

Much of the modern production represents the secret caches of villagers and the work of "bandit diggers." Each team of "thieves" has its own lapidaries, who cut all the rough in some corner of a small apartment in Ekaterinburg. Many stones are poorly cut, although some fine ones are produced. Unfortunately, many are slightly scratched or chipped in handling. Essentially no rough demantoid appeared in the Russian "gem fairs" in 1995, and very little rough reaches the outside market. Although many cut stones (about 15%–20%) are sold in Russia, where there is historic appreciation, the bulk of present production goes "unofficially" abroad, most of it to Germany with lesser amounts finding their way to Israel, the United States, the United Arab Emirates, Spain, Italy, and Canada. The authors' experience is that German dealers, like most Russians, tend to prefer the pale "golden green" stones that best display demantoid's inher-

Figure 15. In some of the newer demantoids to emerge from Russia (see, for example, figure 1), large quantities of randomly oriented acicular inclusions are found throughout the cut stones, with no evidence of a nucleating crystal. Photomicrograph by Shane F. McClure; magnified 20×.



ent brilliance and fire. American dealers usually seek out the much rarer "emerald"-green stones, in which the darkness of the color largely masks the fire (again, see figure 1). The best prices are found in Ekaterinburg at the Urals Exhibition of Colored Stones, held each year in the fall.

CONCLUSION

Demantoid is a beautiful green to yellow-green gem variety of andradite garnet, colored by minor chromium and intrinsic iron. It has great brilliance and "fire" (dispersion), but it is slightly lower in hardness than tsavorite.

Historically, demantoid has been found almost exclusively in Russia's Central Urals. Discovered in the mid-19th century, this bright green gem soon became popular among the nobility of Czarist Russia and even enjoyed brief exposure in Western Europe at the turn of the century. With the onset of the Bolshevik Revolution in 1917, however, exportation of this rare gem came to a halt, and little new material emerged until the economic restructuring (*perestroika*) of the late 1980s.

Two important demantoid districts are known in the Central Urals, one about 115 km north-northwest and one about 75 km south-southwest of Ekaterinburg; each of these districts has two or more alluvial or *in situ* deposits. All of the localities appear to have significant reserves, as to date there has been no systematic or sustained mining of this gem material. Although two deposits are presently leased to Russian companies by the Russian government, neither provides a significant, continuous, or dependable supply of demantoid rough. Neither company has the finances to develop the properties they hold, and thus they are eagerly seeking foreign investment. The Kamenuschka deposit is of special interest, as it yields stones of the most desirable color and presently is not licensed. Unauthorized recovery from river gravels by illegal miners provides most of the present production; unfortunately, there are no reliable statistics for demantoid production—historic or recent—from this area.

In the next few years, the Russian government is likely to assume control of the production, cutting, and distribution of demantoid, as it has recently done with emerald and alexandrite. Demantoid may also be declared a gem of the "first group," which would put it in the company of diamond, emerald, ruby, sapphire, and alexandrite and thus result in more stringent purchase and export regulations.

Political and economic stability in Russia may bring about the development of these world-class deposits. Until then, demantoid will remain a rare and costly gemstone, sought primarily by wealthy collectors and those with a taste for the exotic.

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